Materials Engineering Branch

TIP*

No. 071 Free-machining Alloys

Author(s): Ernest W. Mielke Contact: (301) 286-6882

A number of commonly used metal alloys are designated as free-machining alloys. These are alloys to which additions of certain elements have been made that help to break up the machining chips, allow lower power and produce better finishes and longer tool life. Such free-machining alloys are the copper alloys containing tellurium (Te) and lead (Pb); brasses containing Pb; bronzes, steels and stainless steels containing sulfur (S), selenium (Se) and Pb and the aluminum alloys containing Pb and bismuth (Bi). The most commonly used alloys for spacecraft hardware are the 303 and 416 stainless steels with Se or S, the phosphor bronzes with Pb, the free-cutting brasses with Pb and free-cutting copper alloys with Pb, Te, or Se.

The non-metallic inclusions created by the various additions are points of weakness. If the stock is rod or bar extrusion, both of which have received significant mechanical working in one direction, the inclusions possess a texture (or preferred orientation[1]) parallel to the worked direction. Consequently, if the alloy is stressed, especially in a cyclic fashion, in a direction normal to the worked direction, these inclusions can serve as sites for premature failure, especially via a fatigue mechanism.

Such alloys have been used in the past as rolled or extruded bar stock to machine gears, with the result that the inclusions were oriented parallel to the gear teeth and, therefore, normal to the cyclic stresses applied to them, as shown in Figure 1. In some instances the inclusions have originated fatigue cracks at the roots of the gear teeth.

However, the use of free-machining alloys should be discouraged in space flight application and prohibited in structural applications. The inclusions (that make the alloys free-machining) can lead to undesirable crack growth. This, in turn, leads to poor fracture control predictability.

[1] Carl R. Johnson, "The Importance of a Preferred Grain Orientation in the Fabrication of Metal Parts", NASA MTR 755-006, March 1974.

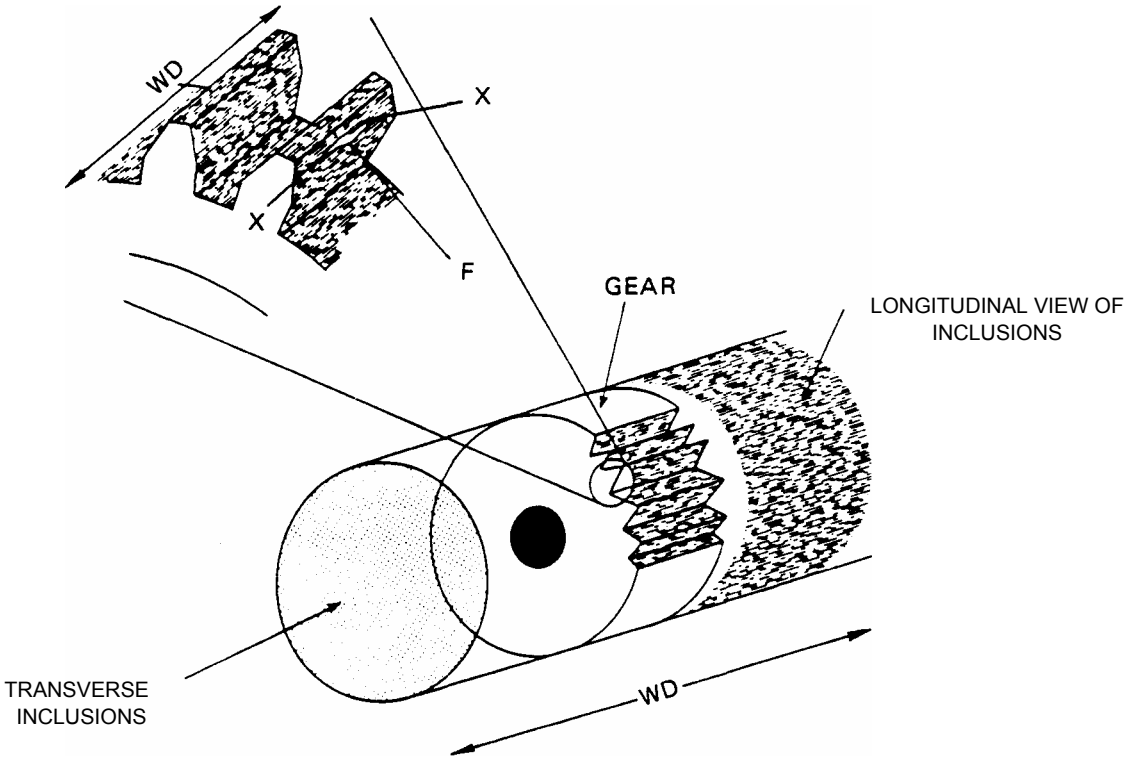

Figure 1. A sketch of a gear machined from a bar, showing the worked direction (WD) and a simulated elongated inclusion represented by X-X. During operation, a force (F) acts on the face of the tooth that could cause the tooth to chip.